

Is it “natural” to expect Economics to become a part of the Natural Sciences?

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We are in the middle of a complex debate as to whether Economics is really a natural science. The general consensus is that *natural science* concerns the description and understanding of natural phenomena, based on observations and empirical evidence. The two discrete branches are Physical and Biological sciences. Mathematics forms the basis of all of the above at different degrees of usefulness. One very important feature of natural sciences is that the facts can be validated accurately, and the repeatability of the findings/results serve as fundamental criteria. Mathematics and logic form the basis of most natural sciences while observations and subsequently quantified facts become *natural laws*. This is more prevalent in natural sciences than in social sciences. On the other hand, social sciences including economics are strongly based on qualitative reasoning, but at the same time, quantitative research forms a substantial part of it.

If we plunge deep into the philosophical aspects of science, the unique characteristic of a scientific methodology is the way of validating its ideas, commonly termed as ‘epistemology’ [1]. The fundamental test of coherence for determining whether the derived conclusions follow from the assumptions logically and whether the arguments are consistent, is still considered by most theoretical economists to be sufficient. They favor logical analysis, and hence the exclusive use of mathematics, bound to “theorems” and “proofs”. The test of coherence is a necessary but not a sufficient condition, when it comes to natural science, as established by scientists and philosophers. What are further required are the tests of *correspondence*, *comprehensiveness* and *parsimony*, which are all empirical in nature. When all three of these tests are met, a theory can be said to have been validated empirically. Social scientists usually point out that it is very difficult to carry out empirical research and so, their theories should be accepted without necessarily passing all these tests. Specifically economists argue that it is difficult or rather impossible to conduct experiments where certain parameters can be controlled. However, these issues asking to relax the mandatory empirical validation of a theory, is at conflict with the course of natural science. It is until not quite recently that approaches have been changing slowly.

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Being trained as a physicist, and having tried my hand on addressing some socio-economic problems, with my little experience and expertise, I will try to analyze the present question to the best of my ability. Here I will not make comments about political economy and related matters of policy making that I have very little idea about. Moreover, in this article, I will argue about economics and social sciences in general.

In the last 2 decades, we have seen a surge in the number of physicists pursuing research in topics which traditionally belong to economics. So much so that even a term *Econophysics* [2–4] has been coined for the cross-disciplinary studies which use mainly physics approach and tools to address economics problems. This in turn triggered many meetings (conferences, symposia, workshops etc.) and subsequently academic journals to support this line of study. Several books have already been written by experts to formalize the course of these studies, and a few universities and institutions have been offering courses since more than a decade now, and even several Ph.D. theses have been written on the topics. This is quite encouraging for the interdisciplinary approach to science in general, although both the communities are still not quite sure of this ‘marriage’ of physics and economics, since there is a feeling that nothing substantial has been achieved compared to the amount of activity that has already taken place. It is somewhat true that economists, being not so liberal to interdisciplinary approaches, do not pay much attention to whatever progress is offered by physicists to their subject. On the other hand, we are often being asked by traditionally grounded physicists, whether *Econophysics* is just a fad. As the saying goes, “*the proof of the pudding is in the eating*”, both communities will pay attention to the need for cross-disciplinary talking only when there is some serious contribution in decoding an ill-understood phenomena. From a lay physicist’s point of view, several intuitively appealing concepts of economics such as efficiency and optimality are rather abstract, and difficult to formalize, and possible alternatives might help in the overall understanding of the subject.

Let us go back in time to see how the disciplines evolved. Sociology and Economics are disciplines in their own right, with a huge body of modern literature developed independently of physical sciences. However, in their infancy, these disciplines were not very distinct from physical science. It is interesting to note that the development of statistical physics was also influenced by social statisticians recording the ‘state’ of a person (statistics as ‘state numbers’) by recording the various measures of his social conditions. Theoretical development of social science was triggered in the name of “Social Physics” à la Adolphe Quetelet [5], and subsequently by Auguste Comte [6]. The development of economic theory through the 19th century saw analogies to physics. One of the founders of modern economics, Irving Fisher was originally trained as a physicist under Josiah

Willard Gibbs, who was in turn among the foremost to lay foundations of statistical mechanics. Of course, one of the most well known facts in the history of modern economics is that many of its ideas have been largely influenced by physical sciences, with their logical basis and technicalities having close resemblance to statistical physics. A classic example is that of Jan Tinbergen, who with his colleague Ragner Frisch, was the first Nobel laureate in Economics (Nobel Memorial Prize in Economic Sciences in 1969) “for having developed and applied dynamic models for the analysis of economic processes”. Tinbergen studied mathematics and physics at the University of Leiden under Paul Ehrenfest, who was one of the key figures in the development of statistical physics. During his years at Leiden, Tinbergen had numerous discussions with Kamerlingh Onnes, Hendrik Lorentz, Pieter Zeeman, and Albert Einstein, all Nobel laureates who left profound contributions to statistical physics. Tinbergen and many other icons of modern economics shaped their ideas with heavy influences from physical science, most of which were already developed in the literature of statistical physics. Another fact in the story of cross-influence is that of the history of the theory of random walk, which was formalized mathematically by Louis Bachelier, in his thesis *Théorie de la spéculation* [7], predating Albert Einstein’s [8] and Marian Soluchowski’s [9] study of Brownian motion.

Social scientists and economists have since then dealt with numerous interesting issues of the human society, uncovering behaviors which seem to be universal. These empirical regularities (or patterns) suggest that they might be predictable from first principles [10], despite the fact that development of society and economics can be influenced heavily by historical events, that might seem to be an integral part to how the society functions. Markets sit at the central point of the economy, where communications take place directly or indirectly, and there exists collective processes of price formation and resource allocation [11], and subsequent rise of social institutions to support all of these. In the quest for the above, physicists and economists approach problems with different goals. As in most natural sciences, physics is propelled by the quest for “universality” [12], what are usually termed as “laws”. The quest for similarity within a diverse set of events lead to this, where several details that make these sets seemingly different are eventually shown to be redundant or “scalable” in some appropriate mathematical form. Social science in general, as also in economics, is more likely to focus on the differences between the same sets.

However, it is also often pointed out that certain patterns observed a couple of decades ago may have changed. This happens due to the fact that certain essential features of human interaction have changed with the advent of technologies. This makes socio-economic systems distinct compared to physical systems – here we rarely find established ‘laws’ [13]. This naturally calls

for a change in the theoretical analysis and modeling, making the field an extremely challenging one. Specifically, there has been wide discussion about addressing socio-economic phenomena in the light of *complexity science*¹ and embracing ideas from various disciplines [14] to understand socio-economic phenomena and a few big initiatives are already taking shape².

Mandelbrot's finding of the power law behavior of price fluctuations [15] and further establishment of the results by different groups, including Gene Stanley's [16] is one of quite a few important contributions made to financial markets. Suddenly powers laws were found everywhere in the financial market data, including the variance in the company growth rate with respect to company size [17], number of shares traded in a transaction, number of trading orders submitted at a specific price relative to the best offered price, size of the price response given the size of a company, among others. Pricing models have seen sufficient contributions [18] from physicists, and studies of stock price movements in analogy to earthquake statistics [19], have engaged the communities to debate. Another important contribution came in the form of studying income and wealth distributions [20, 21]. Since Pareto's observation [22] of the power law in income distributions back in 1897, most theories were confined to economic details. Physicists contributed fresh eyes and a new toolbox, as well as the importance of several fundamental models like kinetic theory [23] which sit at the base of physical sciences, to explaining the nature of income and wealth distributions.

Economists believed that the foundations of the subject was strong enough, yet the standard economic theory failed to foresee the graveness of financial crises that occurred in the last 10 years. Many started to express an opinion about the need for a fresh foundation that took into account the role of heterogeneous agents [24]. Except a very few areas, there is not yet acceptance with open arms for such approaches from mainstream economics, where theories are mostly based on a representative agent, which are attributed to as the reason for the failure of such mainstream theories to predict the economic catastrophes.

More liberal approaches like agent based modeling, specifically focusing on heterogeneous agents, which almost intuitively corresponds to the formalisms developed for the theoretical physics of disordered systems [25, 26], specifically useful being the physics of spin glasses [27]. Agent based modeling is dominated by game theory, of which, most of the theoretical studies are two-agent games, while there is not sufficient literature on multi-agent, or for that matter, study of the case of macroscopically large number of agents. An alternative approach using physics of disordered

¹ M. Buchanan, To Understand Finance, Embrace Complexity, Bloomberg, March 11, 2013. <http://www.bloomberg.com/news/2013-03-10/to-understand-finance-embrace-complexity.html>

² Institute for New Economic Thinking, <http://ineteconomics.org/>

systems has proved to be useful, yet is not a typical economics tool. A culmination of several of these approaches [11, 28] can offer useful alternatives to addressing a variety of problems. Traditional economics is dominated by the assumptions of rational agents, and the ‘representative’ one and their optimizing behavior, which are, time and again proved to be too ideal for the real world. A single agent, household or firm, maximizing their utility makes little sense. Surely they make nice looking theories, with solvable equations, but are indeed far off from reality, as the empirical facts prove. Unless one accepts the reality of ‘interaction’ between economic agents (interaction as in *I react according to how you act*), one is not expected to understand the dynamics of collective activity of a large number of differently motivated, intelligent players with varied information processing capabilities who can, in principle, take a variety of actions. There is already very strong arguments [24] in favor of such an approach which might lead to rather useful things.

The answer to the basic question in our hand, whether *Economics* is yet to qualify as a *Natural Science* is still lurking, although both Economics and Natural Sciences have evolved a lot since such a question was formally raised [29] back in 1898, and repeatedly later [1, 30] within the economics community. The future is ours, it is never too late to start reshaping approaches for good. Accepting ideas and methodologies from natural sciences into economics can only better the understanding and control over an economy.

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